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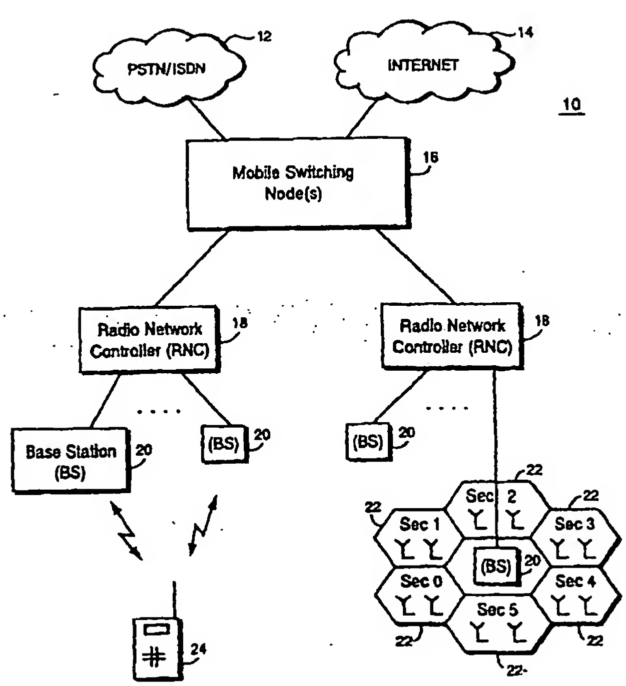

(57) Abstract: In a diversity handover, a destination base station receiver rapidly synchronizes to a mobile station's uplink transmission by strategically locating the search window used by the destination base station multipath searcher. In the example embodiment, the search window is positioned in accordance with a propagation delay associated with the border of the destination base station cell area. if a known signal in the uplink transmission is not detected at the initial search window position, the search window is moved to positions progressively closer to the center of the cell area. The search window may be moved in various patterns in accordance with different search strategies.

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SYNCHRONIZATION OF DIVERSITY HANDOVER DESTINATION BASE STATION

RELATED APPLICATIONS

This application is related to commonly-assigned U.S. Patent Application Serial No. 09/070,788, filed May 1, 1998, entitled "Search Window Delay Tracking in Code Division Multiple Access Communication System," the disclosure of which is incorporated herein by reference.

FIELD OF THE INVENTION

The present invention relates to code division multiple access (CDMA) communication in cellular radio telephone communication systems, and more particularly, to diversity handover synchronization.

BACKGROUND AND SUMMARY OF THE INVENTION

Direct sequence code division multiple access (DS-CDMA) allows signals to overlap in both time and frequency so that CDMA signals from multiple users simultaneously operate in the same frequency band or spectrum. In principle, a source information digital data stream to be transmitted is impressed upon a much higher rate data stream generated by a pseudo-random noise (PN) code generator. This combining of a higher bit rate code signal with a lower bit rate data information stream "spreads" the bandwidth of the information data stream. Each information data stream is allocated a unique PN or spreading code (or a PN code having a unique offset in time) to produce a signal that can be separately received at a receiving station. From a received composite signal of multiple, differently-coded signals, a PN coded information signal is isolated and demodulated by correlating the composite signal with the specific PN spreading code associated with that PN coded information signal. This inverse, de-spreading operation "compresses" the received signal to permit recovery of the original data signal and at the same time suppresses interference from other users.

In addition to receiving signals transmitted from several different transmitting information sources, a receiver may also receive multiple, distinct propagation paths of the same signal transmitted from a single transmitter source. One characteristic of such a multipath channel is an introduced time spread. For example, if an ideal pulse is transmitted over a multipath channel, the corresponding signal appears at the receiver as a stream of pulses, each pulse or path having a corresponding different time delay, as well as different amplitude and phase. Such a complex received signal is usually referred to as the channel impulse response (CIR). Multipaths are created in a mobile radio channel by reflection of the signal from obstacles in the environment such as buildings, trees, cars, people, etc. Moreover, the mobile radio channel is dynamic in the sense it is time varying because of relative motion affecting structures that create the multipaths. For a signal transmitted over a time varying multipath channel, the received corresponding multiple paths vary in time, location, attenuation, and phase.

The existence of multiple paths, however, may be exploited in a CDMA system using signal diversity combining techniques. One advantage concerns signal fading which is a particular problem in mobile communications. Although each multipath signal may experience a fade, all of the multipaths usually do not fade simultaneously. Therefore, a diversity-combined signal output from a CDMA receiver is not adversely affected by a temporary fade of one multipath.

A CDMA receiver employs a multipath search processor that searches for and identifies the strongest multipaths along with their corresponding time delays. One such searcher is described in the above-referenced commonly-assigned application. A RAKE demodulator captures most of the received signal energy by allocating a number of parallel demodulators (called RAKE "fingers") to the strongest multipath components of the received multipath signal as determined by the multipath search processor. The RAKE finger outputs are diversity-combined, after corresponding delay compensation, to generate a "best" demodulated signal that considerably improves the quality and reliability of communications in a CDMA cellular radio communications system.

The multipath search processor, (sometimes referred to herein as simply a "searcher"), identifies the channel impulse response of a complex received signal in order to extract the relative delays of various multipath components. The searcher also tracks changing propagation conditions resulting from movement of the mobile station or some other object associated with one of the multipaths to adjust the extracted delays accordingly.

More specifically, the channel impulse response of a received multipath signal is estimated within a certain range of path arrival times or path arrival delays called a "search window." All signals detected within the search window form the delay profile, but only those signals originated by the transmitter belong to the channel impulse response. The remaining received signals in the delay profile are noise and interference. When the signals forming the delay profile are represented by their respective powers and delays, the delay profile is called a power delay profile (PDP).

The channel impulse response is estimated very frequently so that delay variations of the radio channel can be tracked. In particular, the position of the channel impulse response within the search window frequently changes because of movement of the mobile station or other object motion and because of frequency mismatch of the PN sequence generators used at the transmitter for spreading and at the receiver for de-spreading. As a result, the position of the search window must be adjusted to keep the channel impulse response in the middle of the search window.

Space diversity is attained by providing multiple signal paths through simultaneous links from a mobile station through two or more base stations. When the mobile station is in communication with two or more base stations, a single signal for the end user is created from the signals from each base station. This diversity communication is sometimes referred to as a diversity, "soft" handover in that communication with a destination base station is established before communication with the source base station is terminated. Thus, after a call is initiated and established between a mobile station and a serving base station, the mobile station continues to scan a broadcast signal transmitted by base stations located in neighboring cells. Broadcast signal scanning continues in order to

determine if one of the neighboring base station transmitted signals is strong enough for a handover to be initiated. If so, this determination is provided to the radio network which sends the appropriate information to the mobile station and to the new destination base station to initiate the diversity handover. The new base station searches for and finds the mobile station's transmitted signal using the associated spreading code. The destination base station also begins transmitting a downlink signal to the mobile station using the appropriate spreading code. The mobile station searches for this downlink signal and sends a confirmation when it has been received.

In each cell, the searcher selects the strongest paths for demodulation. The demodulated information from each of these strongest paths are combined using, for example, some form of maximal ratio combining. In addition, the radio network combines the two versions of the mobile station uplink signal from base stations involved in the diversity soft handover and selects either the signal with the best quality or combines the signals to achieve an optimal signal. The result of these various diversity combining operations is a greatly improved resistance to fading and other adverse influences often encountered in mobile radio communications.

Diversity handover requires timing synchronization between the source and destination base stations and the mobile station. Synchronization should be achieved as rapidly and as simply as possible. In the downlink direction (from the base station to the mobile station), the mobile station locates and uses a known pilot signal contained in the base station broadcast channels to temporarily synchronize with the radio network system time. In the uplink direction (from the mobile station to the base station), a known pilot signal transmitted from the mobile station permits the source base station to estimate the channel impulse response for the uplink channel. Using this channel impulse response, the source base station derives synchronization signals necessary to extract the known pilot symbols from the received signal samples. Initial synchronization process occurs after the mobile station performs a random access over an uplink random access channel to acquire a traffic channel from the base station. At the completion of a successful random access procedure, the source base station is synchronized to the first arrived and detected

multipath signal component originated by the mobile station and thereafter extracts pilot symbols later transmitted by the mobile station on the uplink traffic channel.

Regarding synchronization of the destination base station in diversity handover situations, the mobile station measures the frame timing difference between the downlink broadcast channel transmitted by the originating, i.e., source base station and the downlink broadcast channel transmitted by the destination base station. That frame timing difference is communicated via the source base station to the radio network which forwards that information to the destination base station along with the spreading code associated with the mobile station communication. The radio network may then "stagger" downlink frame transmissions from the destination base station so that signals from both base stations arrive at approximately the same time at the mobile station. One such downlink, frame staggering approach is described in commonly-assigned, U.S. Patent No. 5,828,659 entitled "Time Alignment of Transmission in a Down-Link of a CDMA System," the disclosure of which is incorporated herein by reference. The mobile station downlink traffic channel information is provided by the radio network to both source and destination base stations at the same time. Using the frame timing difference, a frame offset/number, and perhaps a timeslot offset from the source base station, the destination base station transmits on the downlink traffic channel. Based on already existing synchronization to the source base station, the mobile station establishes chip synchronization with the downlink traffic channel transmitted by the destination base station. This is possible because the signal from the destination base station arrives approximately at the same time as the signal from the source base station. Therefore, the multipath searcher in the mobile station can locate signal paths from the destination base station within the search window which is already adjusted for the source base station.

During the synchronization procedure for the destination base station, a difficulty arises because there is an unknown propagation delay from the destination base station and the mobile station, and an unknown propagation delay from the mobile station to the destination base station. The sum of these propagation delays is called the round-trip delay, and it determines the delay between the transmit timing of the destination base station and the time when the signal is received at the mobile station. Namely, the mobile

station receives the signal transmitted from the destination base station after a certain propagation delay from the instant when the signal is transmitted. The transmitted signal from the mobile station is synchronized with the received signal at the mobile station, so the transmitted signal from mobile station is delayed with respect to the base station transmission. The additional propagation delay from mobile station to the base station makes the delay of the received signal at the base station equal to the round-trip propagation delay.

The round-trip propagation delay is unknown in diversity handover because there is no random access uplink channel communication between the mobile station and the destination base station like there was with the source base station when the call connection was initially established. During the random access process, the propagation delay between the source base station and the mobile station is measured and used to facilitate the source base station synchronization. Since the round-trip delay between the mobile and destination base station is unknown, the searcher in the destination base station must scan all possible multipaths that could be generated by the mobile station located anywhere in the cell corresponding to the destination base station.

Since maximum delay of the received signal from the mobile station is unknown, a longer search window may be used to cover the maximum possible round-trip propagation delay, which corresponds to the destination base station cell size. As an example, a base station cell having a ten kilometer radius would have a corresponding maximum round-trip propagation delay of approximately eighty microseconds. A typical search window used in the source base station is on the order of ten microseconds. However, the search window in the destination base station would need to be eight times longer in order to accommodate the 80 microsecond propagation delay for this ten kilometer radius cell. Such a long search window is undesirable because of the increased data processing and memory resources required to perform the larger number of search and demodulation operations associated therewith. This large number of operations means increased synchronization delays. A longer search window therefore lessens the ability of the destination base station to respond to changes in the radio channel which translates, ultimately, into increased bit errors in the RAKE receiver outputs.

The present invention provides rapid synchronization of the destination base station receiver to the mobile station's uplink transmission in a diversity handover situation. When a handover of a mobile station connection is initiated to a destination base station, a search window is used by the destination base station searcher to detect a channel impulse response (CIR) of the uplink mobile station transmission received at the destination base station. That search window is initially positioned where the channel impulse response of the mobile station transmission is expected. By initially positioning the search window where the CIR should be, rapid synchronization may be accomplished without having to increase the size of the search window used by the destination base station searcher.

In the example, non-limiting embodiment, the initial position may correspond the border of the cell area for the destination base station. Although the propagation delay between the mobile station and the destination base station is unknown, when a diversity handover is being initiated, it is highly likely that the mobile station is located near the border of the destination base station cell. Consequently, the propagation delay is likely to be at or near a maximum propagation delay for that cell. More specifically, the mobile station uplink transmission includes a known PN code sequence. The search window is located at or near a maximum delay position of the known PN code sequence before despreading the received mobile station uplink transmission with delayed replicas of the known PN code sequence contained in the search window. If the CIR is not detected, the search window is moved to delay positions progressively closer to the center of the cell area in the search for the channel impulse response of the mobile station transmission. The search window may be moved in various patterns in accordance with different search strategies.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other objects, features, and advantages of the invention will be apparent from the following description of preferred example embodiments as well as illustrated in the accompanying drawings in which reference characters refer to the same parts throughout. While individual functional blocks and components are shown in many of the figures, those skilled in the art will appreciate these functions may be performed by

individual hardware circuits, by a suitably programmed digital microprocessor or general purpose computer, by an application specific integrated circuit (ASIC), and/or by one or more digital signaling processors (DSPs).

Fig. 1 is a function block diagram of an example cellular radio communications system in which the present invention may be employed;

Fig. 2 is a drawing illustrating multipath propagation between a mobile station and a base station;

Fig. 3 is a graph showing an example multipath channel impulse response delay profile useful in illustrating principles of the present invention;

Fig. 4 illustrates uplink and downlink communication paths between source and destination base stations;

Fig. 5 is a flowchart of diversity handover synchronization procedures;

Fig. 6 illustrates an example embodiment of a CDMA receiver in which the present invention may be employed;

Fig. 7 illustrates a format of an example information signal;

Fig. 8 is a function block diagram of an example multipath search processor in which the present invention may be advantageously employed;

Fig. 9 is a flowchart illustrating search window positioning procedures in accordance with one example embodiment of the present invention;

Fig. 10 illustrates the positioning of successive search windows during diversity handover synchronization in accordance with one example of the invention; and

Figs. 11A-11C depict various example search strategies.

DETAILED DESCRIPTION OF THE DRAWINGS

In the following description, for purposes of explanation and not limitation, specific details are set forth, such as particular embodiments, circuits, signal formats, techniques, etc. in order to provide a thorough understanding of the present invention. However, it will be apparent to one skilled in the art that the present invention may be practiced in other embodiments that depart from these specific details. In other instances, detailed descriptions of well-known methods, devices, and circuits are omitted so as not to obscure the description of the present invention with unnecessary detail.

The present invention is described in the context of a CDMA (preferably wideband CDMA) mobile radio telecommunications system 10 as shown in Fig. 1. A representative, circuit-switched, external core network shown as cloud 12, may be for example the Public Switched Telephone Network (PSTN) and/or the Integrated Services Digital Network (ISDN). A representative, packet-switched, external core network shown as cloud 14, may be for example the Internet. Both core networks are coupled to one or more service nodes. For simplicity, only a single block of mobile switching nodes 16 is shown that provides circuit and/or packet switching services. The mobile switching node 16 is connected to a plurality of radio network controllers (RNCs) 18. Each radio network controller 18 establishes and releases a particular radio channel (i.e., one or more spreading codes) between one or more base stations (BSs) 20 and mobile station (MS) 24. Accordingly, the RNCs manage the selection and allocation of spreading codes and diversity handovers. The base station 20 handles the wideband CDMA radio interface to mobile station 24 and includes radio equipment such as transceivers, digital signal processors, and antennas required to serve each cell and cell sector in the network. As shown for one base station 20, each base station may include multiple sectors 22, and each sector preferably includes two diversity antennas.

The mobile station 24 is depicted with call connection legs with two base stations 20 to illustrate a diversity handover. Each leg includes an uplink connection and a downlink connection. The base station where the call is already established is the source

base station (BS_S) and the base station to which a new leg is being established is called the destination base station (BS_D).

Fig. 2 illustrates a simplified, dynamic multipath propagation model. While multipath propagation must be addressed by both mobile stations and base stations, for description purposes only, the multipath example illustrates a signal being transmitted from a mobile station 24 to a base station 20. The transmitted signal is received at the base station 20 the by the diversity antennas in plural sectors 22 with each received signal having multiple paths P1, P2, and P3. Path 1 is the direct, first received, and often the strongest path. Path 2 is reflected off a stationary object such as a building. Path 3 is reflected off a moving object such as an automobile. The mobile station 24 may be also be moving. The basic problem then for the receiver in both an origination and a destination base station is to identify each received path to determine its magnitude and relative delay so those paths may be diversity-combined taking into account their respective delays.

Fig. 3 illustrates a graph showing an example delay profile for received signals within a search window. The vertical axis of the graph is received signal power. The horizontal axis shows delay time intervals related to the rate at which the received signal is sampled. The waveform is the estimated channel impulse response and includes four peaks having a magnitude that exceed a detection threshold. Only the three peaks corresponding to paths P1, P2, and P3 are valid multipaths. The fourth peak is a false peak, but because it exceeds the threshold, it is also identified as the path. Path 1 corresponds to delay $\tau 1$, path 2 corresponds to delay $\tau 2$, and path 3 corresponds to delay $\tau 3$.

The purpose of the search window is to encompass the channel impulse response (at least the significant multipaths of the received signal) plus an additional offset so that the window is somewhat wider than the portion of the channel impulse response containing valid multipaths. More formally, the search window is defined by the number of delay values used as starting positions for correlating the received signal with the PN code in order to cover the maximum expected delay of the last-arrived, detected multipath component with respect to the first-arrived, detected multipath component. In this non-

limiting example, the number of complex samples corresponding to the maximum expected multipath delay is 160, and therefore, N_{window} equals 160 delay positions. If there are four samples per chip, a 160 sample window corresponds to 40 chips. The center of the search window, ($N_{window}/2=80$ delay positions or 20 chips) is preferably aligned with the center of the channel impulse response. This assures that the channel impulse response including the strongest valid multipaths is contained within the search window for processing, e.g., demodulation. Otherwise, there is a risk of missing one or more multipath components.

In this regard, the search window delay tracking procedure described in the above-identified application is a preferred way of centering the search window with the center of the channel impulse response. Simply choosing the strongest or the first-arrived path as an alignment point for the search window does not yield particularly accurate results because either one of these alignment points fluctuates according to fading or noise, and consequently, the search window is not centered around the channel impulse response. Instead, the center of the search window is aligned with a mean or average delay value of the channel impulse response. The mean delay is determined by averaging the delays of each of the multipaths of the channel impulse response. The difference or error ε between the center of the search window $N_{window}/2$ (at delay position 80 in Fig. 3) and the mean delay location (at a delay position slightly less than 80) is detected and minimized by adjusting the location of the search window (or by making some other adjustment).

Reference is now made to Fig. 4 which illustrates a diversity handover scenario where a mobile station is located on the border of a source cell corresponding to a source base station (the source cell radius is indicated by dashed lines) and the border of a destination base station cell (indicated using a dotted line). There is a downlink propagation delay D_S from the source base station to the mobile station and an uplink propagation delay $)_S$ from the mobile station to the source base station. Similarly, there is a downlink propagation delay D_D from the base station to the mobile station and an uplink propagation delay $)_D$ from the mobile station to the base station. As described above, the source base station establishes a communication link with the mobile station. The mobile

station also receives broadcast overhead messages from neighboring base stations and determines those base stations having sufficiently strong signals to place them in an active base station set. This typically occurs when the mobile station approaches the border of the source base station cell which often overlaps the cell border of a neighboring cell as shown in Fig. 4. At this point, it is desirable to initiate communications with the destination base station and begin diversity handover by establishing two-way communication between the mobile station and one or more destination base stations.

The time difference between the signals transmitted from source and destination base stations can be quite large. As described in the above-referenced, commonly-assigned U.S. Patent No. 5,828,659, the time difference between source and destination base station signals is determined and used to achieve synchronization using, for example, a frame staggering procedure. More particularly, the time difference between the mobile station's receipt of the source base station's transmitted signal and receipt of the destination base station's transmitted signal is measured by the mobile station. The time difference is sent back by the mobile station to the radio network controller via the source base station. The difference in mobile reception times is used to stagger frames of data thereby synchronizing the two base stations involved in the diversity handover. Specifically, the destination base station is informed by the radio network controller of the time offset that should be used for its downlink traffic channel connection. When data for the mobile arrives from the radio network controller, the destination base station compensates for the downlink difference between propagation delays D_S and D_D by buffering the data until the appropriate channel frame so that the mobile station receives both signals from the source and base stations at about the same time.

The destination base station must also compensate for the round-trip propagation delay (D_D+)$_D$) between the received signal from mobile station and the destination base station transmission timing in order to synchronize to the mobile station's uplink transmissions. Namely, the mobile station receives the signal transmitted from the destination base station after a certain propagation delay from the instant when the signal is transmitted. The transmitted signal from the mobile station is synchronized with the received signal at the mobile station, so the transmitted signal from the mobile station is

initially delayed with respect to the base station transmission. The additional propagation delay from mobile station to the base station makes the delay of the received signal at the base station with respect to the base station transmission equal to the round-trip propagation delay.

The flowchart in Fig. 5 outlines a general diversity handover synchronization procedure (block 30). A connection is established between the mobile station and a source base station (block 32). The mobile station measures the signal strength of downlink transmissions from neighboring base stations and reports those signal strengths to the radio network controller via the source base station (block 34). When the signal strength from a neighboring base station is sufficiently high for a diversity handover, a communications link between the mobile station and destination base station is initiated (block 36). Downlink transmissions from both the source and destination base stations to the mobile station are staggered or delayed to achieve synchronization as described above (block 38). The destination base station compensates for an round-trip propagation delay between the mobile station and the destination base station in order to synchronize with uplink transmissions from the mobile station (block 40).

In compensating for the round-trip propagation delay, the destination base station is at a disadvantage compared to the source base station. The destination base station lacks the random access procedure that allows the respective downlink and uplink trip propagation delays D_s and)$_D$ between the mobile station and the source base station to be determined and taken into account by the source base station. Because the propagation delay between the mobile station and the destination base station is unknown, the destination base station searcher might be forced to scan all possible delays of the known pilot code PN sequence transmitted by the mobile station. To do so, the destination base station searcher must consider all possible time delays of the known PN code sequence up to a worst case scenario where the mobile station is located at the edge of the cell border. The number of time delays corresponding to the radius of the destination base station cell defines an uncertainty region considerably larger than a typical (like that used for the source base station) search window used to track the various paths of a channel impulse response.

Rather than lengthen the search window with its increased data processing, memory, and delay, the present invention strategically positions a smaller-sized search window at or near the destination base station cell border, e.g., at the maximum radius of the cell. Positioning the search window at a point or location along the radius of the cell means positioning the search window at a delay position in the known PN code sequence that corresponds to the round-trip propagation delay between that point or location and the destination base station. For that initial point and corresponding delay, the searcher despreads the received signal looking for the channel impulse response (CIR) of the signal received from the mobile station. More specifically, the portion of the known PN sequence within the window at its current delay position is correlated with the received signal. The magnitude of the correlation is compared with a threshold to detect the CIR.

If the CIR is not detected, the search window is moved from the PN code sequence delay position corresponding to the border of the cell (or close to the border) toward the center of the cell. Using this approach, the channel impulse response corresponding to the mobile uplink transmission to the destination base station will likely be obtained early in the search process since the mobile station is near the border of the destination cell in diversity handover. By starting the search from at or near the maximum expected delay corresponding to the destination cell radius, and moving the search window incrementally towards a near zero delay at the center of the cell, the searcher locks onto the CIR much quicker, and the average synchronization time for the destination base station is significantly reduced. This approach also permits a relatively short window to be used effectively reducing the data processing resources and delays.

With the multipath illustration of Fig. 2 and the graph in Fig. 3 in mind, (including the parameters defined in Fig. 3), reference is now made to an example base station receiver 50 in Fig. 6. A RAKE demodulator 54 includes a plurality of RAKE finger demodulators (not shown) which receive inputs from a PN sequence generator 58 (i.e., a PN de-spreading code sequence) and from a timing control unit 56. The timing control unit 56 generates synchronization (SYNC) signals provided to the RAKE demodulator 54 and to a multipath search processor 60 also connected to the RAKE demodulator 54. Preferably, but not necessarily, signals from two diversity antennas 0 and 1 for each six

base station sectors (0-5) are input to respective automatic gain control (AGC) circuits 52. Each AGC circuit is connected to a corresponding antenna to reduce the long term dynamic range of the received signal, thereby reducing the required number of bits for signal representation but at the same time preserving the information content of the signal. Analog-to-digital conversion can be performed before or after AGC and therefore is not explicitly shown in the figure. The multipath search processor 60 calculates delay profiles for each of the sectors using those output samples. Further description may be found in the commonly-assigned, above-referenced patent application. The signal samples are also provided to the RAKE demodulator 54 for de-spreading and combining. The combined output signal is generated using a number of antenna signals from different sectors selected by the multipath search processor according to the strongest multipaths received by all of the base station sectors.

While the present invention is directed specifically to the multipath search processor 60, a brief, general understanding of how the base station receiver processes received signals is helpful in understanding the present invention. Pilot symbols or other known signals transmitted from the mobile station are used by the source and destination base stations to estimate the channel impulse response. As mentioned earlier, the source base station derives initial synchronization signals necessary to extract periodically inserted pilot symbols from the received signal samples via a random access procedure employed by mobile radios over a known uplink access channel used to initially acquire a traffic channel from the source base station. After successful completion of the random access procedure, the source base station is synchronized to the first-arrived, detected multipath signal component originated from the mobile station. That initially received synchronization signal is used to extract pilot symbols subsequently transmitted on the traffic channel. Further adjustment of the synchronization signal is the task of a window delay tracking unit in the searcher 60 shown in Fig. 8. Again, the destination base station in a diversity handover process does not have the benefit of the random access procedure to synchronize initially with uplink transmissions from the mobile station.

In order to understand the use of pilot symbols, reference is made to Fig. 7 which shows an example data transmission format in which information is transmitted

from the mobile station. Information symbols are formatted at the highest level as consecutive superframes provided to appropriate spreading circuitry in the mobile station transmitter. The superframe information is spread using a PN code sequence assigned by the base station to the mobile station and transmitted over the radio interface. Each superframe, (which may be for example 840 milliseconds), may include for example 64 consecutive radio frames, where each radio frame may be 10 milliseconds. Similarly, each 10 millisecond radio frame may include 16 time slots, and each time slot includes pilot or known symbols used for synchronization and channel symbols containing unknown information symbols to be demodulated and communicated to the base station.

Assuming initial synchronization is acquired in the source base station, reference is now made to the multipath search processor 60 illustrated in additional detail in Fig. 8. The signal received by each automatic gain control unit 52 includes the signal transmitted by the mobile station. Each of the automatic gain control circuits 52 is connected to base station selector 62 which selects blocks of signal samples from both antenna signals from each base station sector. Again, while sectors and antenna diversity are employed in the example embodiment, it is understood that the present invention is not restricted to antenna diversity or to base stations with sectors. For example, the invention may be applied to a simple, non-sectored base station with only a single antenna.

Each base station sector has a corresponding one of M channel estimators 64, where M equals the number of base station sectors. The selector 62 extracts blocks of signal samples to be searched for known symbols, e.g., pilot symbols, and provides those blocks to their corresponding channel estimator 64. The channel estimators 64 perform code-matched filtering with coherent and non-coherent integration of the code-matched filter responses. In coherent integration, complex correlation values obtained in a number of successive time slots for the same delay of the block of received signal samples are added together. In non-coherent integration, the powers of coherently-integrated correlation values are summed. For each antenna, the corresponding channel estimator 64 delivers an average power delay profile corresponding to the estimated channel impulse response to the path selection unit 66. The path selection unit 66

discriminates between signal and noise samples in the M delay profiles and then selects a number of strongest path signals to be demodulated in the RAKE demodulator 54.

The corresponding path delays τ, and powers P of the N paths selected by the path selection unit 66 are provided to a window tracking unit 70. The number N of selected paths should be equal to the number of RAKE fingers, but N can also be smaller if there are not enough paths with powers above the detection threshold. These selected paths form a selected channel impulse response as defined above. The window tracking unit 70 keeps the multipath channel impulse response in the middle of the search window. The search window position is corrected using a search window position correction signal from the window tracking unit 70 provided to the timing control block 56 via a search window position control 72. During the soft diversity handover, the search window position control 72 sets the initial position of the search window at or near the destination base station cell border and shifts the search window from a position of maximum delay in the PN code sequence toward a position of minimum delay in the PN code sequence if the search at the initial window position is not successful. As long as the search is not successful, the search window position correction signal Wcorr(n) at the input of 72 is ignored. Alternatively, during the diversity handover, the window tracking unit 70 is deactivated. The output W(m) of the search window position control 72 adjusts the timing output from timing control 56 which adjusts the phase of PN generator 58. By adjusting the phase, i.e., the state, of the generated PN code sequence applied to the channel estimator 64, the search window position is effectively adjusted. When the diversity handover is finished, the search window position control 72 passes the signal Wcorr(n) from the window tracking unit 70 to the timing unit, i.e., W(m)=Wcorr(m).

Another function of the window tracking unit 70 is to adapt the selected path delays $\tau_1', \ldots, \tau_N'$ in accordance with the search window adjustments. A chip synchronization unit 68 determines whether an initial synchronization process is completed, and if so, sets a chip sync flag. The chip synchronization unit 68 detects that chip synchronization has been achieved if there is at least one selected path, with arbitrary power P_k, that exceeds a detection threshold in the path selection unit 66.

Reference is now made to a search position window flowchart diagram (block 100) illustrated in Fig. 9. A search window analysis is initiated by the search window position control 72 beginning at or near a maximum estimated known or pilot PN code sequence delay corresponding to (or close to) the destination base station cell border (a larger radius) rather than that a minimum delay corresponding to (or close to) the center of the cell (a smaller radius) (block 102). As described above, the searcher 60 correlates the received signals for the various multipaths to the particular delayed version of the pilot PN code sequence encompassed by the window at its current position to determine corresponding CIR path delays and powers for paths detected within that window (block 104). A decision is made whether the channel impulse response has been detected (block 106). If not, a decision is made in block 107 whether the sliding search window has reached the end of its "slide" or movement toward the minimum delay.

In some search patterns, this slide end point may correspond to (or be close to) the zero delay or center of cell position. In other search strategies described below, this may correspond to some intermediate delay position between the maximum and minimum delay. If the slide end point has been reached, the search window is either returned to the maximum delay position estimated for the cell border in block 102 or the search window is moved back towards the maximum delay position, e.g., incrementally, performing the processing path delay and power operations within the search window as indicated in block 104. If not, the search window position control 72 increments or slides the search window one or more delay positions toward the center of the cell corresponding to zero delay (block 109). The despreading and CIR detection procedures are repeated for each new search window position. On the other hand, if the channel impulse response is detected, the multipath searcher aligns the center of the channel impulse response with the center of the search window (block 110), and the destination base station completes synchronization with the mobile station.

Fig. 10 illustrates a search window sliding strategy that may be used as one example implementation of the present invention. An uncertainty region corresponding to the radius of the destination base station cell in this non-limiting example corresponds to eight times the size of the search window. The search window N_{window} is equal to 40 chips

which corresponds to 160 samples if each chip is sampled four times. Thus, the uncertainty region for this particular cell corresponds to 320 chips or 1280 samples. The search window position signal W(m) generated by the search window position control 72 is determined as follows:

$$W(m) = W(m-1) + N_{window}$$

where N_{window} is the total number of search delays within the search window and m is the iteration ordinal number. For example, the iteration rate may be equal to the frame rate.

Positions of successive search windows are shown within the PN code delay uncertainty region. The time at which the searcher 60 spends at a given window position corresponds to the searcher update time, i.e., the time required to produce the new estimate of the channel impulse response, sometimes also referred to as the "dwell time." If the search window reaches the end of the uncertainty region without locating the channel impulse responds, the search may be begun again from the initial start position at the maximum delay with W(m) equal to 280 chips. This search strategy is depicted in Fig. 11A.

Rather than sliding the search window from the maximum delay to the minimum delay in linear fashion as depicted in Fig. 11A, the search window may be moved from maximum delay to a first lesser delay position, e.g., W(m+1), and then returned to the maximum delay if the channel impulse response is not detected. Thereafter, the search window slides to a next smaller delay, e.g., W(m+2), and returns the search window to the initial maximum delay position if the channel impulse response is not detected. Fig. 11B depicts this search strategy. Each iterative "pass" of the search window becomes larger until the full uncertainty region is covered in a single pass. Alternatively, this same approach of incrementally increasing sliding window passes may be modified so that rather than returning the search window immediately to the maximum delay position to repeat the search or another pass, the sliding window may be incrementally moved back to the maximum delay before moving on to the next pass. Fig. 11C depicts this search strategy.

The present invention significantly reduces the time and data processing resources required to synchronize the destination base station during diversity handover.

The time required to search the entire uncertainty region corresponding to the destination base station cell radius is much greater than the time required to search just a portion of that uncertainty region where the channel impulse response is most likely to be detected. Indeed, using the present invention, there is a high probability the channel impulse response will be detected in only a small portion of the time it would take to search the entire uncertainty region. Moreover, a relatively small search window may be used effectively in this approach reducing data processing needs and further decreasing synchronization time.

While the present invention has been described in terms of a particular embodiment, those skilled in the art will recognize that the present invention is not limited to the specific example embodiments described and illustrated herein. Different formats, embodiments, and adaptations besides those shown and described as well as many modifications, variations, and equivalent arrangements may also be used to implement the invention. Accordingly, it is intended that the invention be limited only by the scope of the claims appended hereto.

WHAT IS CLAIMED IS:

1. A diversity handover synchronization method including establishing a connection between a source base station (20) and a mobile station (24), characterized by:

initiating a diversity handover of the connection to a destination base station, and

synchronizing a downlink transmission from the source and destination base stations to the mobile station,

compensating an uplink transmission from the mobile station to the destination base station for a propagation delay between the mobile station and the destination base station.

2. The method in claim 1, wherein the diversity handover synchronization method is performed in a code division multiple access (CDMA) communication system where the mobile station uplink transmission includes a known pseudo-noise (PN) code sequence, and the compensating step includes locating a search window at a first expected location of the known PN code sequence before despreading the received mobile station uplink transmission.

3. The method in claim 2, wherein the first location is at or near a maximum delay value used as a starting position for despreading the received mobile station uplink transmission.

4. The method in claim 3, further comprising:

if the known PN code sequence is not detected at the first location of the search window, performing another search iteration after moving the search window to a second location having a delay value less than the maximum delay value.

5. The method in claim 4, wherein the position of the search window W(m) is changed for each search iteration in accordance with the following:

$$W(m) = W(m-1) + N_{window},$$

where N_{window} is a total number of delays within the search window, and m is an iteration number.

6. The method in claim 5, wherein the iterative search is continued until the known PN code sequence is detected or until a predetermined delay value is reached.

7. The method in claim 6, wherein the predetermined delay value is at or near zero delay.

8. The method in claim 6, wherein the predetermined delay value changes each time the search window is returned to the first location.

9. The method in claim 4, wherein when the search window reaches a predetermined delay value, yet another search iteration is performed with the starting position of the search window moved to a third location have a delay value greater than the second location delay value.

10. The method in claim 1, synchronizing the destination base station with a transmission from the mobile station using a search window to detect a channel impulse response (CIR) of the mobile station transmission received at the destination base station at a first position where the CIR of the mobile station transmission is expected.

11. The method in claim 10, wherein the first position corresponds to a position at or near a border of a cell area associated with the destination base station.

12. The method in claim 11, further comprising:

moving the search window to detect the CIR of the mobile station transmission received at the destination base station at a second position corresponding to a position closer to a center of the cell area than the first position.

13. The method in claim 10, further comprising:

repeatedly moving the search window from the first position to a position closer to the center of the cell area to search for the CIR of the mobile station transmission.

14. The method in claim 13, wherein if the search window is moved to a predetermined position, returning the search window to the first position.

15. The method in claim 14, wherein the search window is returned to the first position incrementally.

16. The method in claim 14, wherein the search window is returned to the first position immediately.

17. The method in claim 14, wherein the predetermined position is at or near a second position close to a center of a cell associated with the destination base station.

18. The method in claim 14, wherein the predetermined position is between the first position and a second position close to a center of a cell associated with the destination base station.

19. The method in claim 18, wherein the predetermined position is progressively closer to the center of the cell each time the search window is returned to the first position.

20. A base station (20) comprising:

transceiving circuitry (50) for transmitting a signal to and receiving a signal from a mobile station over a radio interface, and

a multipath search processor (60) including:

a channel estimator (64) configured to estimate a channel impulse response (CIR) for the received signal and generating a delay profile within a CIR search window;

a path selector (66) configured to select paths from the delay profile generated by channel estimator and generating a delay and a magnitude for each selected path; and

a search window positioning unit (72) configured to position the CIR search window to compensate for a propagation delay associated with the received signal.

21. The base station in claim 20, wherein the base station is a destination base station in a handover operation.

22. The base station in claim 21, wherein the search window positioning unit configured to position the CIR search window at a first location corresponding to a cell border associated with the base station.

23. The base station in claim 22, wherein if the CIR of the received signal is not detected at a current window position, the search window positioning unit is configured to move the window from the first location to a second location corresponding to a position closer to the base station.

24. A code division multiple access (CDMA) communication system (10) comprising:

a radio network controller (18);

a source base station (20) and a destination base station (20) coupled to the radio network controller; and

a mobile station (24), while communicating with the source base station, initiating communication with the destination base station,

wherein the destination base station initiates a search for a known signal transmit by the mobile station by locating a search window at a first position corresponding to a position at or near a border of a cell area for the destination base station.

25. The code division multiple access (CDMA) communication system in claim 24, wherein the destination base station subsequently moves the search window to a second position between the cell border and the cell center.

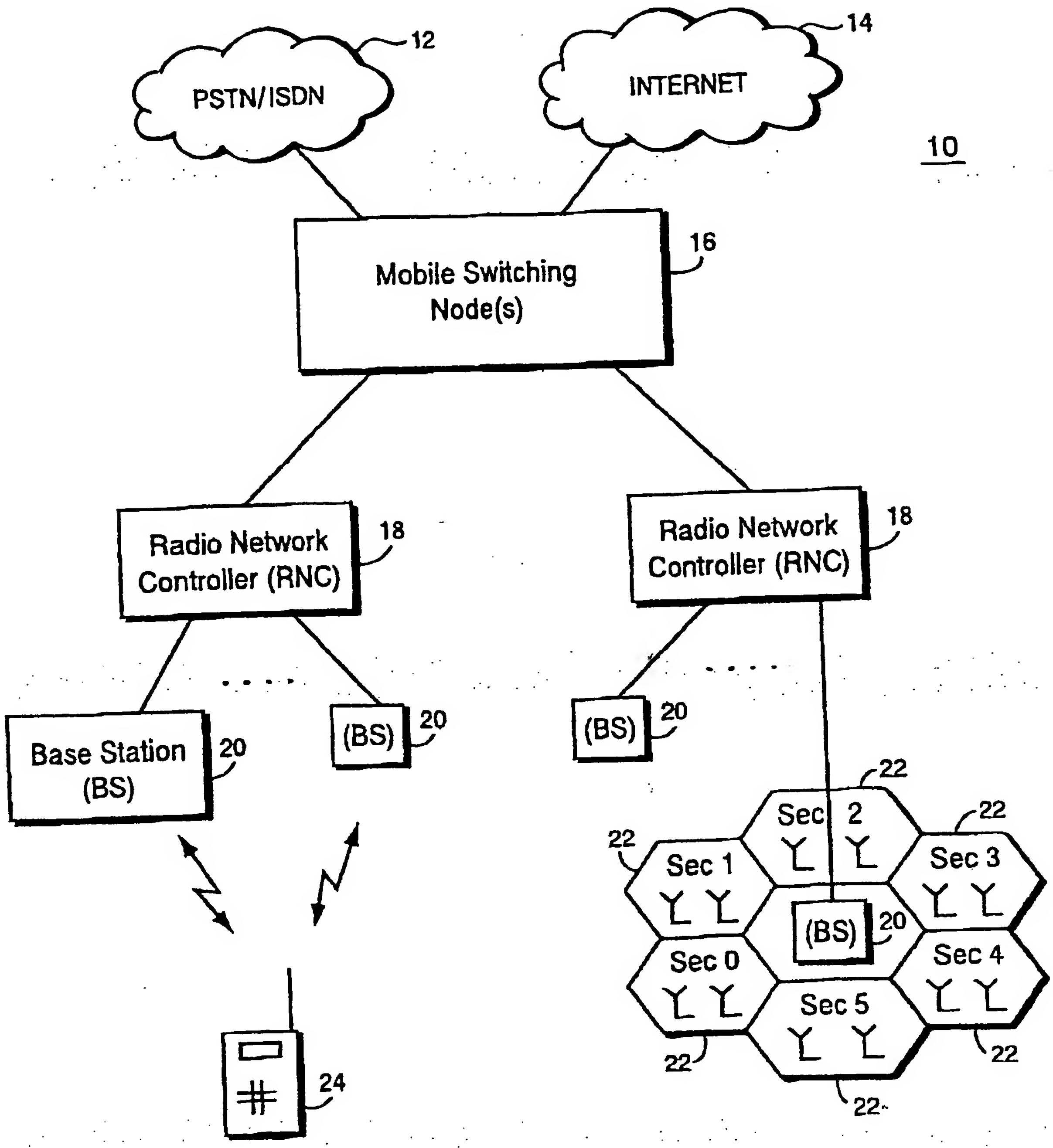

PSTN/ISDN
12
INTERNET
14
10
Mobile Switching Node(s)
16
Radio Network Controller (RNC)
18
Radio Network Controller (RNC)
18
Base Station (BS)
20
(BS)
20
(BS)
20
Sec 2
Sec 1
Sec 3
(BS)
20
Sec 0
Sec 4
Sec 5
22
24

Fig. 1

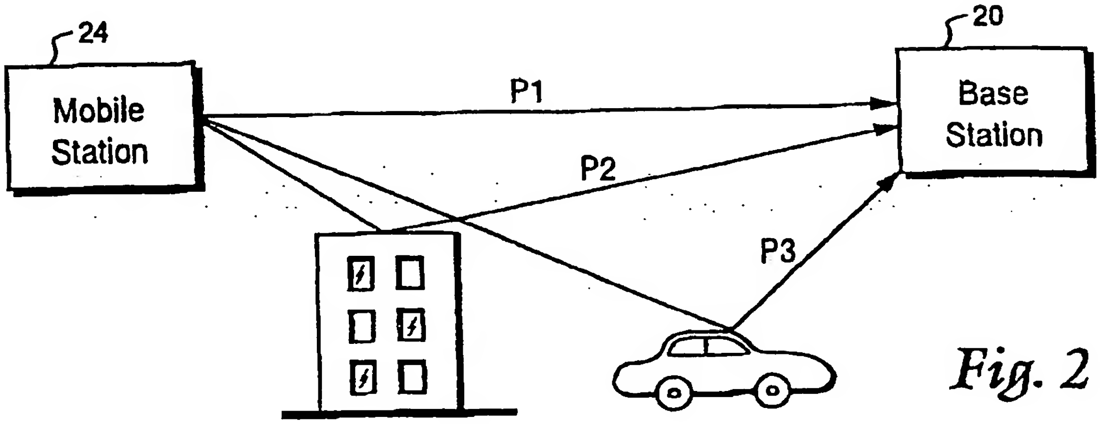

24
Mobile Station
20
Base Station
P1
P2
P3

Fig. 2

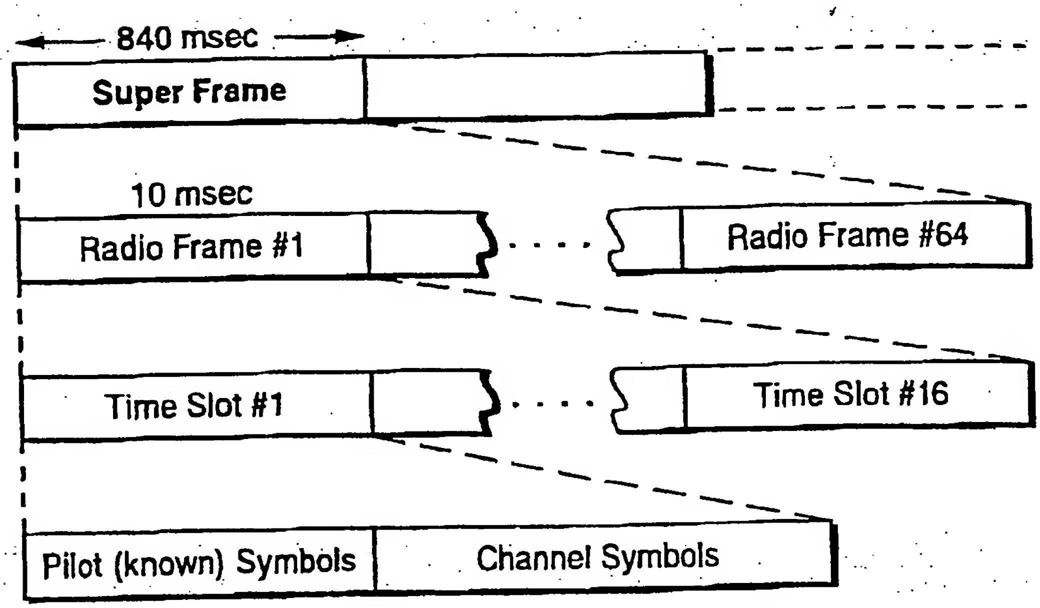

840 msec
Super Frame
10 msec
Radio Frame #1
Radio Frame #64
Time Slot #1
Time Slot #16
Pilot (known) Symbols
Channel Symbols

Fig. 7

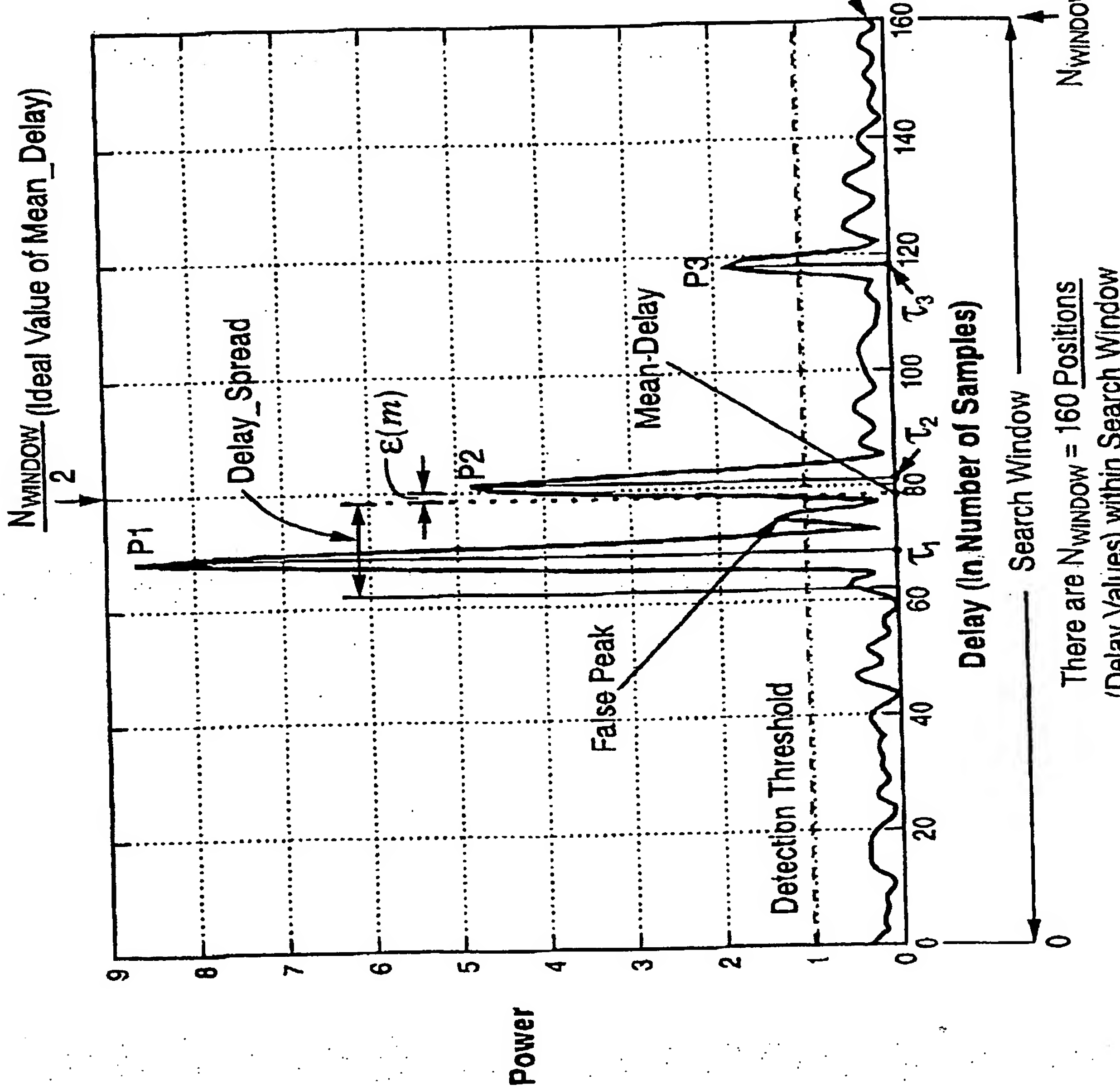

N_WINDOW / 2 (Ideal Value of Mean_Delay)
Delay_Spread
ε(m)
P1
P2
P3
Mean-Delay
False Peak
Detection Threshold
159
Power
Delay (In Number of Samples)
Search Window
There are N_WINDOW = 160 Positions
(Delay Values) within Search Window
N_WINDOW-1
0 1 2 3 4 5 6 7 8 9
0 20 40 60 80 100 120 140 160

Fig. 3

Fig. 4

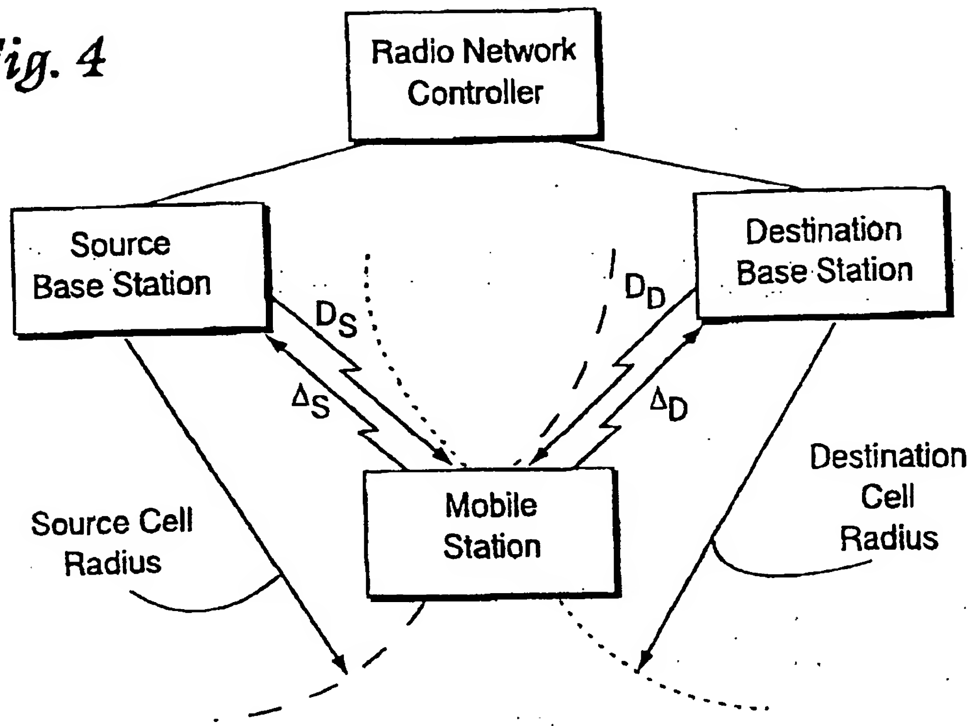

Radio Network Controller
Source Base Station
Destination Base Station
D_S
Δ_S
D_D
Δ_D
Mobile Station
Source Cell Radius
Destination Cell Radius

Fig. 5

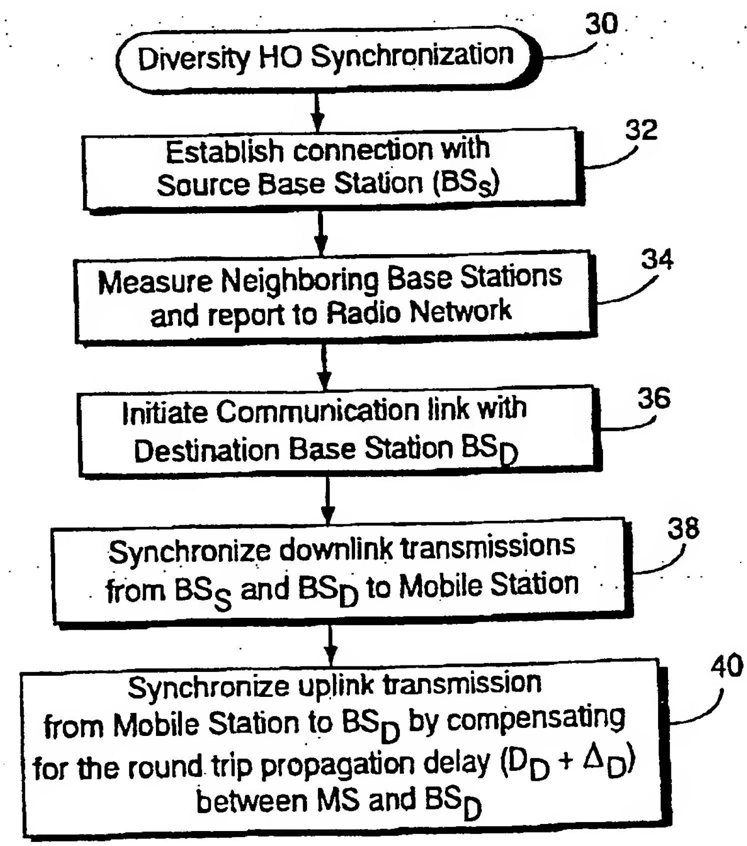

Diversity HO Synchronization
30
Establish connection with Source Base Station (BS_S)
32
Measure Neighboring Base Stations and report to Radio Network
34
Initiate Communication link with Destination Base Station BS_D
36
Synchronize downlink transmissions from BS_S and BS_D to Mobile Station
38
Synchronize uplink transmission from Mobile Station to BS_D by compensating for the round trip propagation delay ($D_D + \Delta_D$) between MS and BS_D
40

Fig. 6

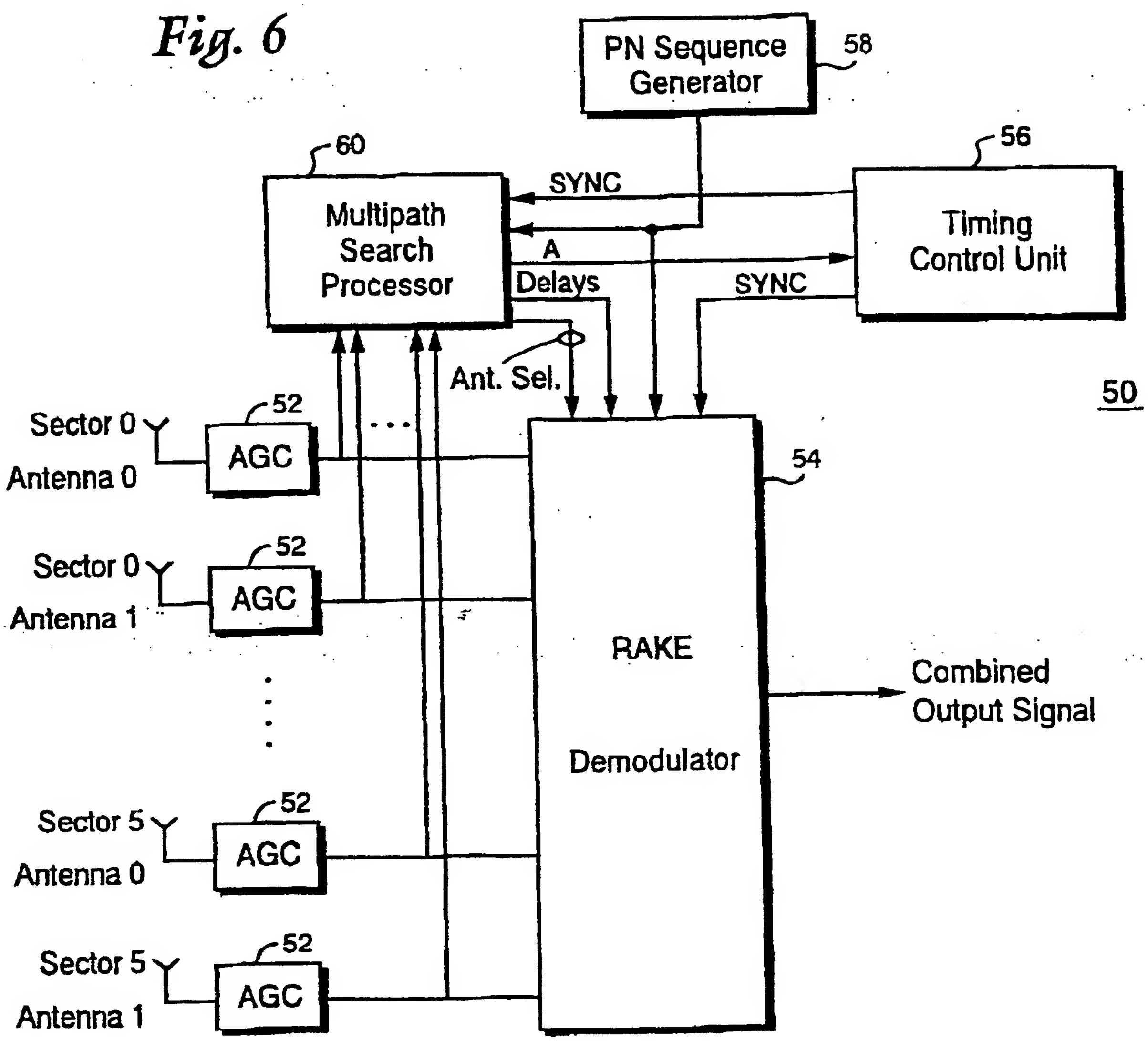

PN Sequence Generator
58
60
56
Multipath Search Processor
SYNC
A
Delays
SYNC
Timing Control Unit
Ant. Sel.
50
52
Sector 0
Antenna 0
AGC
54
52
Sector 0
Antenna 1
AGC
RAKE
Demodulator
Combined Output Signal
52
Sector 5
Antenna 0
AGC
52
Sector 5
Antenna 1
AGC

Fig. 8

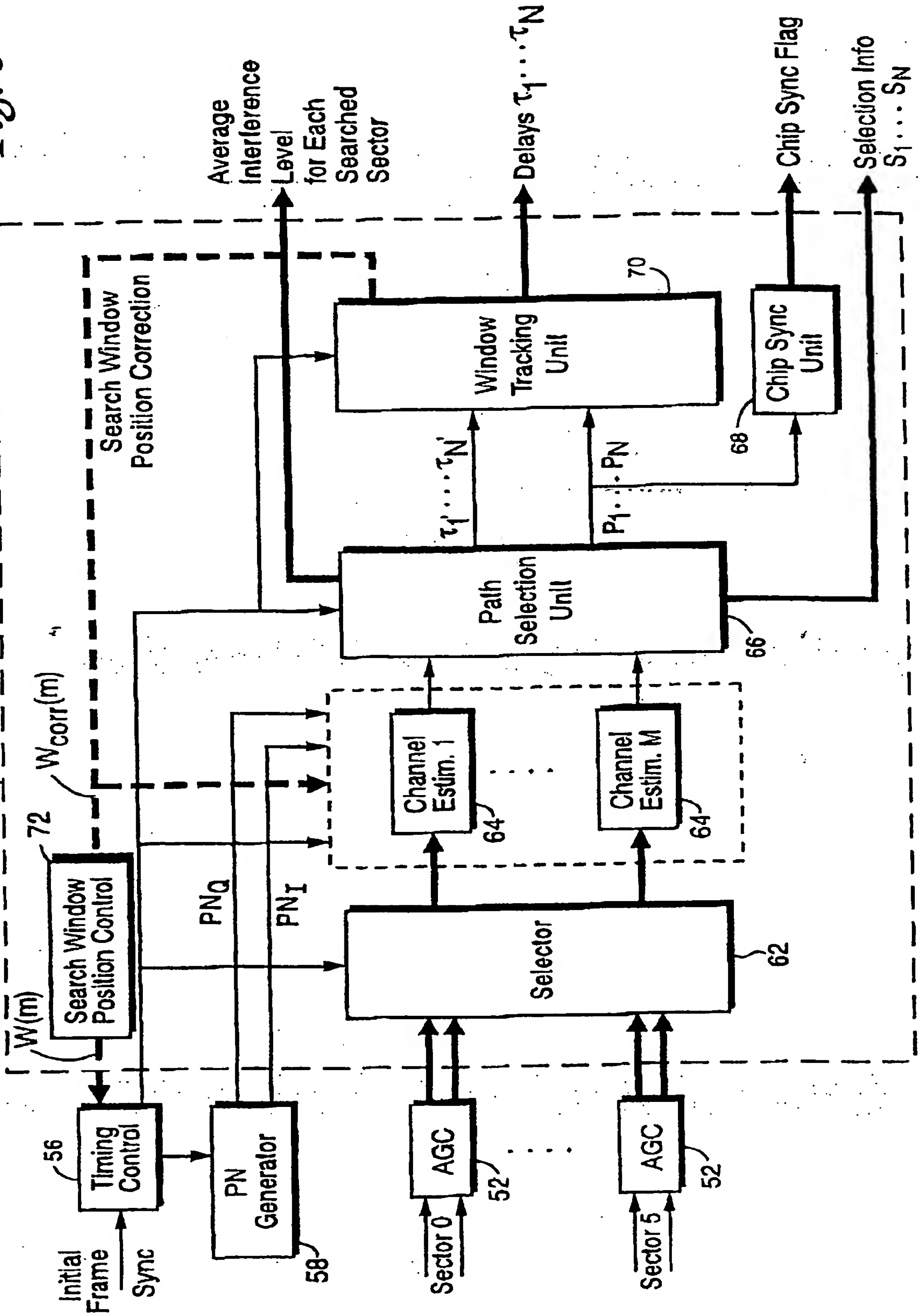

Average Interference Level for Each Searched Sector
Delays $\tau_1 \cdots \tau_N$
Chip Sync Flag
Selection Info $S_1 \ldots S_N$
60
Multipath Search Processor
Search Window Position Correction
70
Window Tracking Unit
Chip Sync Unit
68
$\tau_1' \cdots \tau_N'$
$P_1 \ldots P_N$
$W_{corr}(m)$
Path Selection Unit
66
72
Search Window Position Control
W(m)
Channel Estim. 1
Channel Estim. M
64
64
PN_Q
PN_I
Selector
62
56
Timing Control
Initial Frame Sync
PN Generator
58
AGC
52
Sector 0
AGC
52
Sector 5

Fig. 9

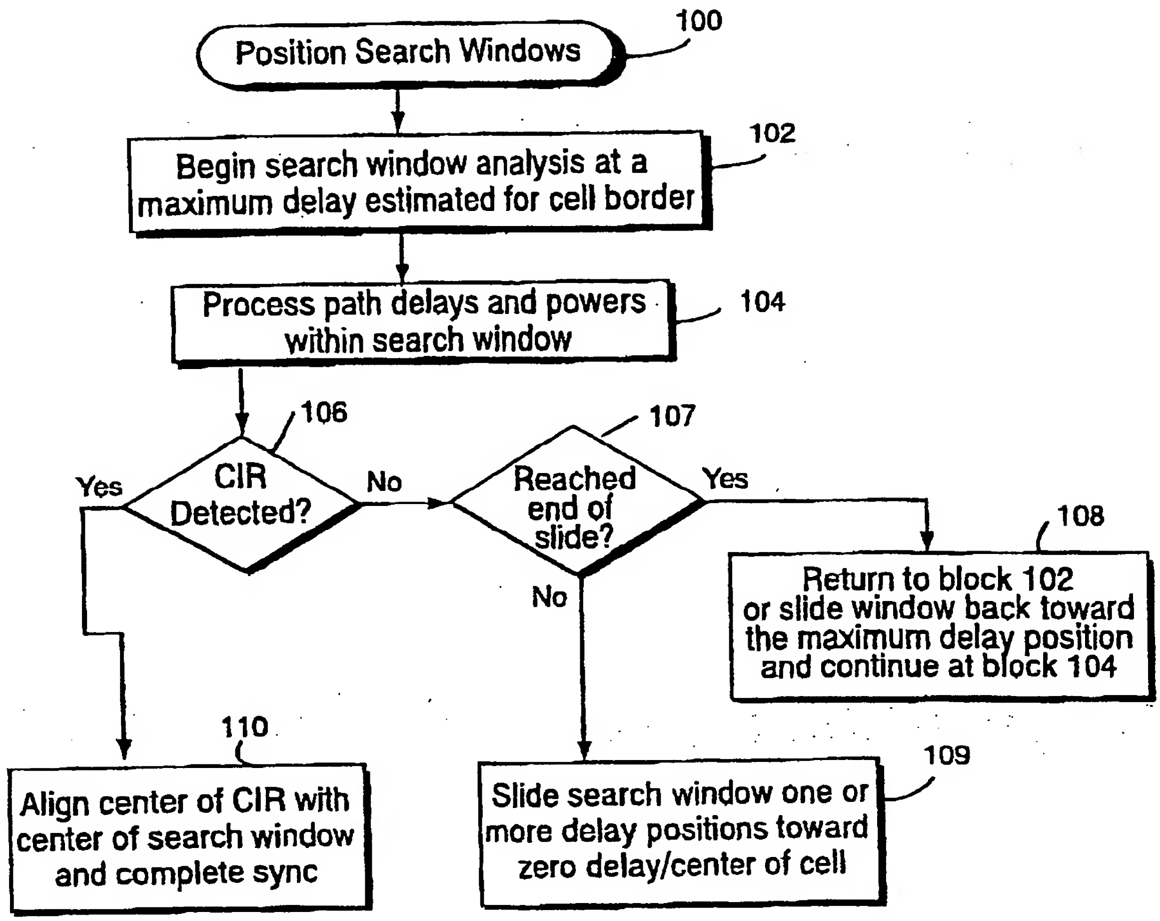
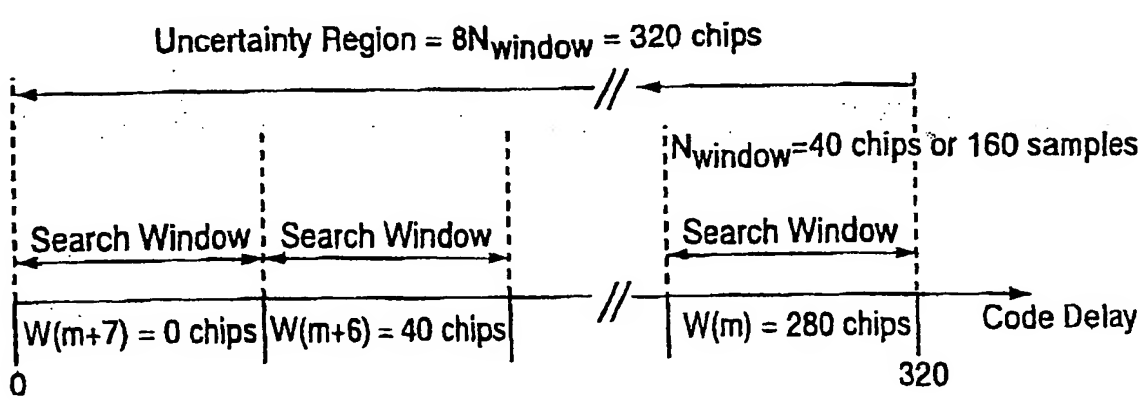

Position Search Windows
100
Begin search window analysis at a maximum delay estimated for cell border
102
Process path delays and powers within search window
104
106
CIR Detected?
Yes
No
107
Reached end of slide?
Yes
No
108
Return to block 102 or slide window back toward the maximum delay position and continue at block 104
110
Align center of CIR with center of search window and complete sync
109
Slide search window one or more delay positions toward zero delay/center of cell

Fig. 10


Uncertainty Region = 8N_{window} = 320 chips
N_{window}=40 chips or 160 samples
Search Window
Search Window
Search Window
W(m+7) = 0 chips
W(m+6) = 40 chips
W(m) = 280 chips
Code Delay
0
320

Search Strategy

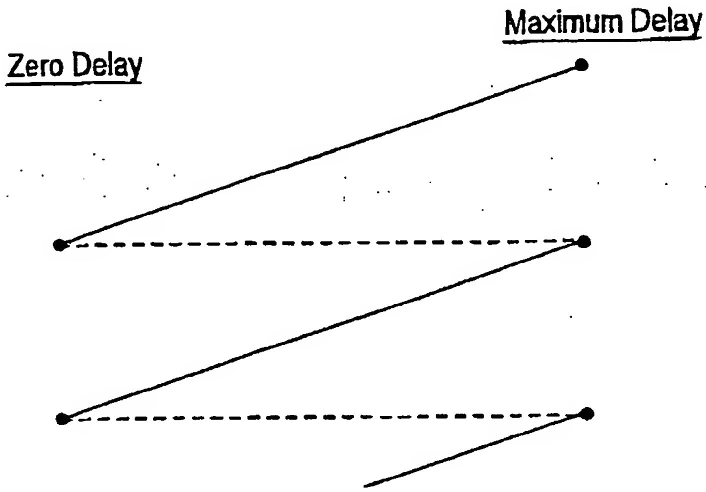


Fig. 11A

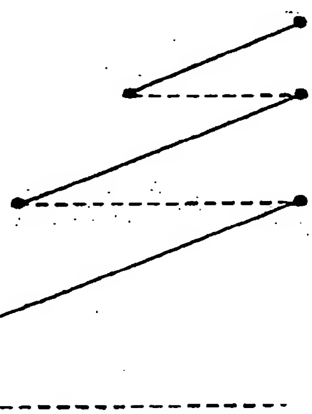


Fig. 11B

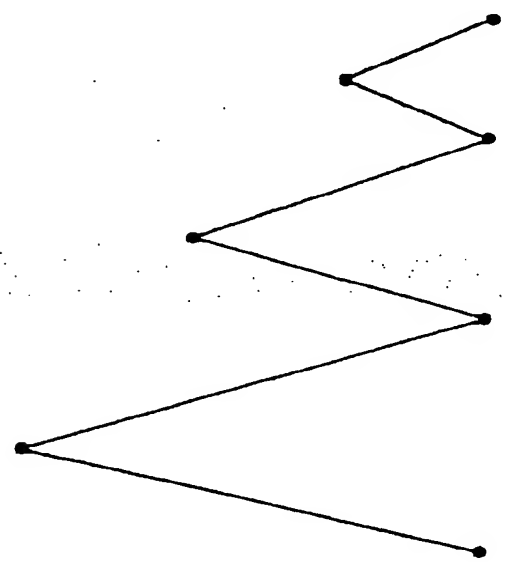


Fig. 11C

INTERNATIONAL SEARCH REPORT

International Application No
PCT/SE 00/02396

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04Q7/32 H04L7/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04Q H04L H04J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X,P	WO 99 63677 A (ERICSSON TELEFON AB L M) 9 December 1999 (1999-12-09) page 4, line 30 -page 8, line 7 page 10, line 30 -page 11, line 28 abstract; claims 1,2; figures 4-11 ---	1-25
X	US 5 881 058 A (CHEN JIANGNAN) 9 March 1999 (1999-03-09) column 2, line 11-62 column 5, line 14-20; claim 1; figure 4 abstract ---	1-25
X	US 5 652 748 A (JOLMA PETRI ET AL) 29 July 1997 (1997-07-29) column 2, line 7 -column 3, line 25; claim 1; figures 1-4 abstract -----	1-25

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
20 March 2001	19. 04. 2001
Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Authorized officer Pär Heimdal

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

Inte .onal Application No

PCT/SE 00/02396

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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		AU 673464 B	07-11-1996
		AU 7658894 A	10-04-1995
		CN 1116033 A	31-01-1996
		DE 69418448 D	17-06-1999
		DE 69418448 T	28-10-1999
		EP 0670098 A	06-09-1995
		WO 9508901 A	30-03-1995
		JP 8503833 T	23-04-1996
		NO 952002 A	13-07-1995